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Session on Storage and Transport of High Burnup Fuel

REGULATORY PERSPECTIVE ON
HIGH BURNUP FUEL STORAGE AND
TRANSPORTATION ISSUES IN SPAIN

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Spain

NRC's Regulatory Information Conference
Washington DC, March 2013



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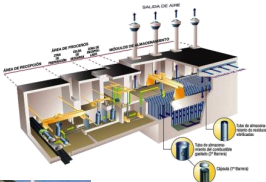


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01 | Fuel Cycle






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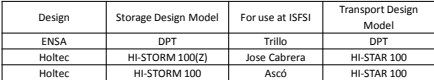
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01 | ISFSI




Design	Storage Design Model	For use at ISFSI	Transport Design Model
ENSA	DPT	Trillo	DPT
Holtec	HI-STORM 100(Z)	Jose Cabrera	HI-STAR 100
Holtec	HI-STORM 100	Ascó	HI-STAR 100



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01 | Centralized Storage Facility

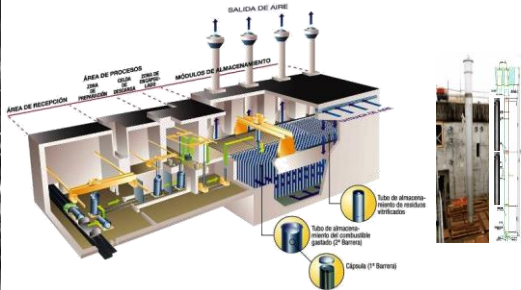



Diagram illustrating the layout of a Centralized Storage Facility. The facility is divided into several functional areas: AREA DE RECEPCIÓN (Reception Area), AREA DE PROCESADO (Processing Area), AREA DE ALMACENAMIENTO (Storage Area), and MODULOS DE ALMACENAMIENTO (Storage Modules). The diagram shows the flow of spent nuclear fuel from the reception area through processing and into storage modules. Key components labeled include: SALIDA DE AIRE (Air Outlet), Tubería de ventilación (Ventilation Pipe), and Cables de alimentación (Power Cables). A detailed view of a storage module shows it contains multiple fuel assemblies (elementos de combustible) and is equipped with a cooling system (sistema de refrigeración).

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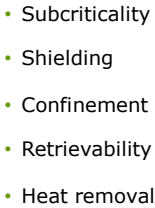
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01 | Regulatory Requirements



- Subcriticality
- Shielding
- Confinement
- Retrievalability
- Heat removal

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02 | Subcriticality

- Use of burnup credit (BUC) methodologies for Criticality Safety Analysis:
 - Licensed since 1990 for pool storage
 - Full BUC (all isotopes) for PWR spent fuel pools
 - Credit to burnable poison (Gd) for BWR
 - Currently licensed for dry casks
 - Only actinides and a few selected fission products are included
- Expected evolution for dry casks:
 - Use of additional fission products

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02 | Subcriticality issues for HB fuel

- Validation of the burnup calculation:
 - Need for additional experimental assay data for high enrichment and high burnup fuel
 - Measurement campaigns performed by Spanish organizations (CSN, Enresa, ENUSA) with participation of ORNL
- Axial burnup distribution impact on reactivity ("end-effect"):
 - The effect on reactivity increases with burnup
 - Not bounding end-effect estimation methods have been submitted


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02 | Subcriticality issues for HB fuel

- Misloading events:
 - The effect of the event on reactivity increases with burnup
 - Current guidance requires an analysis if a measurement of the fuel burnup is not performed
 - The analysis of the misloading event has always been required in Spain so far

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Classifying SNF



- Fuel undamaged based on function:
 - SNF storage and subsequent transportation
 - SNF condition at the time of loading
 - Impact of alteration (degradation) mechanisms
- Issues:
 - Effect of Hydrogen and hydrides on the cladding mechanical properties
 - Behavior of highly corroded cladding
 - Oxide spallation
 - SCC of the top nozzle joint to the skeleton

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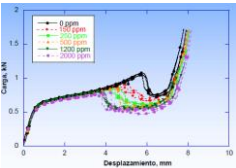
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Effect of hydrides




- Hydride formation promotes cladding embrittlement:
 - Hydrogen concentration
 - Non-uniform hydride distribution: hydride rim



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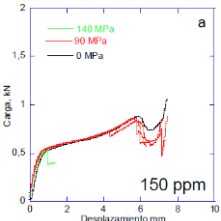
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Effect of hydrides



- Orientation of hydrides: radial hydrides



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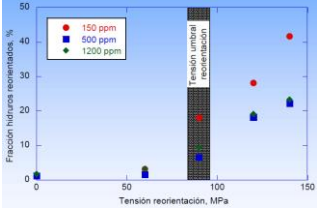
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03 | Effect of hydrides



- Hydride re-orientation conditions: dependence on the temperature history and hoop stress on the cladding



Tensión reorientación (MPa)	150 ppm (%)	500 ppm (%)	1200 ppm (%)
0	0	0	0
50	0	0	0
80	0	0	0
100	0	0	0
110	28	18	0
120	42	22	0
130	0	0	42

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03 | Excessive corrosion



- Population of fuel assemblies showing highly corroded cladding
- Cladding wall thinning due to the thickness of the oxide and of the hydride rim:
 - Decreased resistance
 - Mechanical properties affected by the high Hydrogen contents
 - Higher hoop stresses on the cladding
 - The material should be more prone to hydride re-orientation

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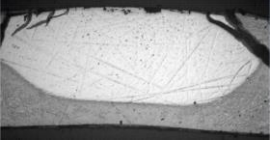
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03 | Oxide Spallation




- Population of Zry-4 fuel assemblies showing oxide spallation
- Behavior of spalled cladding under bending or impact loads:
 - Formation of hydride lenses
 - Mechanical properties of spalled cladding



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04 | Summary



- Relevant high burnup fuel storage and transportation compliance issues have been described
- Methodology issues and code validation needs for BUC application still remain
- The understanding of the effect of cladding corrosion and hydriding should be improved in order to predict cladding failure
- R&D activities are ongoing to address these issues, in collaboration with other Spanish organizations

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